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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FRANK BRUCE INGERSOLL

ENTITLED BACK-FILLING OF TRENCHES

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering.

Ira O Baker

HEAD OF DEPARTMENT OF Civil Engineering.

Back-filling of Trenches

The best methods of re-filling trenches is a subject of great importance in connection with the laying of pipe lines in cities and towns. This is especially true when a trench is opened in a principal street, or where a pavement is to be laid soon after the trench is back-filled. In either case settlement of the material in the trench is undesirable as it causes an uneven surface, and may lead to dangerous conditions.

Shrinkage is sure to occur if the back-filling is improperly or carelessly done, and the settlement may take place in one of two ways; viz:

either the material settles as a whole, thus causing a depression; or the material in the lower part of the trench may settle, a hard crust forming at the surface which may break through and cause a serious accident from which a heavy damage suit may result.

As there is little or no reliable data on this subject, the writer has chosen it for his thesis investigation, and will discuss the various methods of back-filling in an endeavor to arrive at a definite conclusion as to the best way of performing the work with different materials and under different conditions.

The investigation is divided into two parts: 1, The Experience of

Others; 2, Experiments by the Author.

Part 1.

Experience of Others.

Three articles on the subject of back-filling trenches are all that the author has been able to find. Professor I. O. Baker of the University of Illinois presented a brief article in 1901-02 "Technograph."* Professor Baker calls attention to the large number of cases in which settlement occurs in trenches, and attributes it to one of two causes: either the work of back-filling was carelessly done,

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* Technograph,—A scientific paper published annually by the Engineering Societes of the College of Engineering of the University of Illinois.

or the method pursued was not suitable to the material and conditions. He discusses the different methods in use and points out the necessity that the work shall be carefully done in order to secure good results.

Mr. E. A. W. Hammatt, on Dec. 8, 1897, read a paper on Backfilling Trenches, before a meeting of the New England Water Works Association.* Mr. Hammatt seems to have had considerable experience with pipe laying and presents fully the results of his observations, together with

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* For a complete abstract of this paper and the succeeding discussion, see Journal of the New England Water Works Association. March 1898. Vol. 12.

a criticism of some of the specifications under which back-filling is done. He also gives some data showing the shrinkage of various earths, and the space occupied by different sizes of pipe.

Another paper on the subject was read before the Association Jan. 12, 1898, by Mr. E. H. Gowing.* In his discussion the subject of expense is considered more prominently than in Mr. Hammatt's paper.

The following is a review of these three articles, including the opinions of a number of prominent engineers of wide experience.

Natural Settlement. A common method of back-filling where

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*See note preceding page.

the excavation is in unpaved streets, is to cast back loosely the material taken out, heaping it into a ridge over the trench. The result is a settlement directly over the trench and a ridge on each side where the material used in re-filling rests on the undisturbed earth. Authorities differ as to the advisability of using this method in any case.

Professor Baker thinks that although the material may under certain conditions eventually settle to the original level, the damage due to even a temporary ridge will generally be more than the cost of properly filling the trench in the beginning. This is probably true where the street is used to any extent or where an

effort is made to keep it in good condition. In a small town, however, where the original condition of the streets is bad, this method may be the most satisfactory.

Mr. E. A. Taylor in a discussion of the subject says that he filled two miles of trench with a road machine, leaving a good crown. A settlement occured after the first rain and the machine was run over again to fill the holes. He claims that the streets were left in a condition satisfactory to the town, and the cost was comparatively small.

Although it may in rare cases be advisable to loosely back-fill trenches, it is certain that in streets where traffic is at all heavy or where

pavements are to be laid, some other method should be followed.

Flushing. Where water can be had cheaply and in abundance it may be best to flood the trench. This method is strongly favored by some, while by others it is considered bad practice.

Professor Baker says in this connection that if the soil is such that the trench will drain rapidly, flushing will compact the material so that no trouble will be experienced with settlement. He contends that this method should be used only with sand or gravel, and that the material should be added in layers not exceeding 8 to 10 inches thick, each layer being flushed with a stream

of water having sufficient force to wash the finer particles into the voids between the larger ones.

An objection sometimes raised to flushing is that the material shrinks away from the sides of the trench. This will happen if the trench is flooded and the material thrown in all at once.

Most engineers in flushing trenches put in a top layer dry, so as not to produce a mud hole.

A contractor of Cambridge, Mass., used an ingenious method to settle back-filling with water. He had laid a 48-inch pipe in a trench 12½ feet deep and 7 feet wide. After filling the trench nearly full of earth, he saturated the material by the use

of a fire hose with a play pipe about 6 feet long, the play pipe being shoved down to within 3 or 4 feet of the bottom of the trench. When the ground stopped settling and the water came to the surface he would repeat the operation at a distance of 4 or 5 feet. After getting in all the water necessary, he put on the top material leaving it fairly well crowned, and about a week later ran a steam roller over it. The results obtained by this method were very good, and the amount of water used was considerably less than if the puddling had been done in the usual manner. The soil in this instance was sandy.

Tamping. If water can not be used on account of expense

or if the material is clayey soil, the back-filling should be tamped.

Professor Baker cites three conditions that are necessary to make the method of tamping successful. (1) The material shall be moist enough to be plastic, but neither too wet nor too dry. (2) It must be deposited in layers not more than 3 or 4 inches thick. (3) Each layer shall be rolled or tamped. If these three conditions are fulfilled there is no reason why good results can not be obtained. That it is necessary that the material be plastic is evident, since if it is too wet tamping will do no good; and if it is too dry, it will not compact. Authorities are agreed that only a very thin layer of earth

is affected by tamping, 4 inches being considered the maximum thickness. The third condition is the most important and the most difficult to fulfill, since the tendency of the labourers engaged in tamping is to shirk their work; but if the proportion of tampers to shovelers be large and if the work is under good supervision, this difficulty may be overcome.

The experience of a large number of engineers goes to show that better work will be done with a light rammer than with a heavy one. A man will lift a tamper weighing 8 or 10 lbs., about three times as high as one weighing 20 or 25 lbs; and even if he exerts no muscular

force in the blow, the impact of the lighter weight will be the greater.

It is important that the earth in the bottom of the trench be well compacted but it is difficult to tamp around the pipe. Mr. C. H. Gowing* suggests the use of a special rammer similar to that shown in Fig. 1.

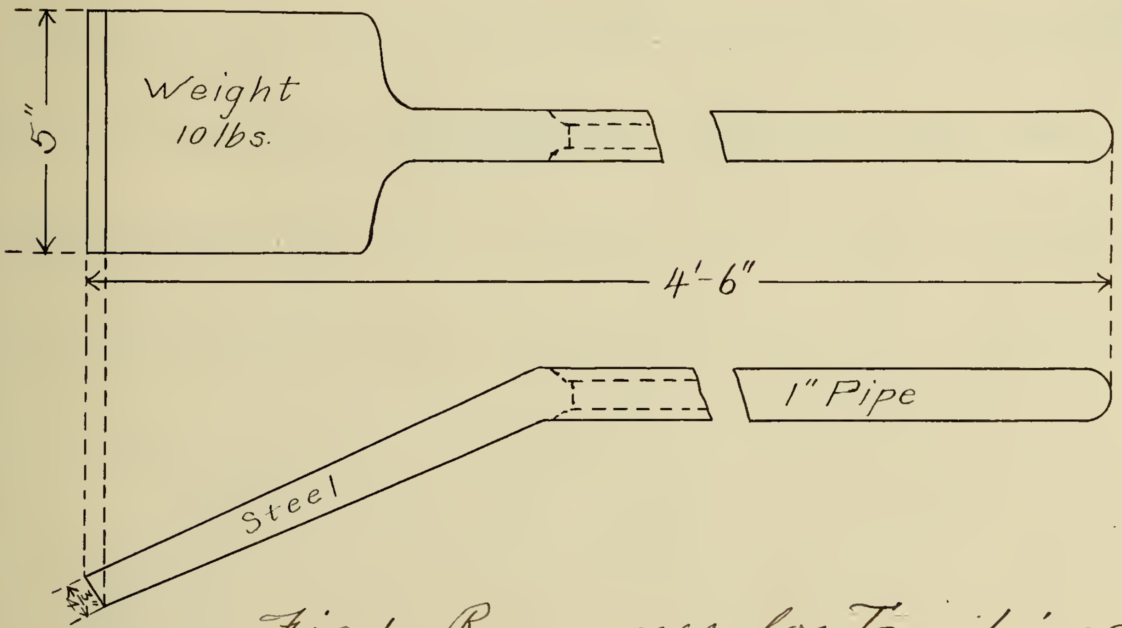

Fig. 1. Rammer for Tamping around Pipes.

Mr. Beals says that his

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* See note p. 4

experience has shown that it is better to use a rammer like that in Fig. 1, and tamp well along the edges of the trench, rather than to attempt to compact thoroughly all the way across.

Replace all the Material. It is sometimes specified that all the material taken from a trench shall be replaced, and in a large number of cases good results will be obtained by such a method. Of course the space occupied by the pipe must be allowed for, but this may easily be calculated for any given case and the amount of material to be left over thus determined.

Use of Sand. Some engineers recommend that trenches be refilled with sand or gravel, which if

flushed in properly will give little or no settlement. This method has been tried in Chicago and pronounced successful, but in cities where sand is not readily obtainable the cost would be prohibitive.

Part 2.

Experiments

As there is great difference of opinion among engineers as to the best method of compacting the various materials used for back-filling, the author and his classmate, Mr. H. M. Price, conducted several experiments with different earths in order to determine the best method of filling trenches under different conditions. Several trenches were excavated and back-filled in the fall, and were ab-

lowed to remain undisturbed until spring, when observations were taken to determine the effect of time and frost. The time elapsing between the back-filling of the trenches and the date on which the final measurements were made was about six months, and it is thought unlikely that any further change would have occured. None of the trenches had traffic passing over them. Cases are known where settlement has occured several years after back-filling, but the trenches in these instances were in streets and surface crusts had been formed by the traffic, so that the street level was preserved until a load sufficiently heavy to break through it was brought upon the crust, when it was found

that extensive settlement had taken place in the lower part of the trench. This settlement probably occured within six months after the trench was re-filled, especially if the work was done in the fall.

Tamping. The experiments to determine the results of tamping were carefully conducted and in no case did any settlement occur. In fact had not the trenches been accurately staked out, it would have been impossible to find them after one or two rain storms. These experiments were made with loam and clay, the material in some cases being comparatively dry and in others very wet, and the results would seem to indicate that tamping should

always be employed. It must be remembered, however, that the tamping was very well done in every case, much better in fact than could be accomplished ordinarily in actual practice.

It is a well known fact that ordinary tamping does not affect a layer of earth of greater thickness than about 6 inches. In these experiments the material was tamped in layers 3 to 4 inches thick, and as in every case all the material was returned to the trench and no settlement occurred, it is evident that the earth was well compacted for the full thickness of the layers. A 12 lb. wooden tamper was used, the dimensions of the face being 6×8 inches.

The trenches in every case

were 6 feet long, 2 feet wide, and $4\frac{1}{2}$ feet deep, the upper 2 feet being black loam, and the lower $2\frac{1}{2}$ feet being clay.

No trench was entirely refilled with clay but in one case this material was kept separate and replaced in the bottom of the trench to a depth of $2\frac{1}{2}$ feet. The clay in this instance was moist, having about the consistency of moulding sand, and it tamped very well, the lumps breaking up readily and compacting in the trench. In another case, however, where the clay was very wet, it became almost impossible to tamp it, as slippery lumps were formed which could only be broken up with great difficulty.

Loam was treated in a

similar manner and it was found that when this material contained just sufficient water to cause it to stick together when squeezed in the hand, it could be compacted in the trench very readily; but when the amount of water present was much greater the earth became very sticky and adhered to the tamper, making it necessary to clean the tool every two or three minuets.

<u>Flushing</u>. Several trenches were re-filled by flushing the material. Three methods of flushing were employed. 1. Refilling the trench at once, keeping the surface of the water constantly above the earth. 2. Refilling in layers 6 to 8 inches thick and allowing the water to soak away

through each layer before putting in the succeeding one. 3. Refilling in layers as before and flushing each layer with a strong stream from a nozzle until all large lumps were broken up.

The trenches like those in the tamping experiments were 6 feet long, 2 feet wide, and 4½ feet deep. The materials treated were clay, loam, and loam mixed with sand.

As would be expected, the greatest settlement occurred when the first method was employed. Only one trench was re-filled by this method, the back-filling material being loam mixed with clay, and a surface settlement of 2¼ inches was observed. Over half of this settlement took place while the water used in flushing was sinking

away. The remainder occurred after a a few rains.

The results obtained when layers were allowed to stand until the flushing water had sunk below the surface were more satisfactory. The greatest surface settlement was ½ inch, the material in this case being loam and clay mixed. With loam and sand no appreciable settlement was found.

The best success in flushing was obtained when the third method mentioned above was employed. Where the trenches were filled with black earth or sandy loam the work proceeded very rapidly as the lumps readily broke down under the action of the stream. Clay was,

however, much harder to handle by this method, more time being required to do the work, and a larger amount of water being necessary.

It appears from these experiments that good results may be obtained by flushing when the material is of such character that all large lumps readily break up under the action of water. Also the flushing water should rapidly drain away, as by this action the smaller particles of earth are carried down and lodge between the larger ones, thus forming a compact mass. Soil with much clay in its composition forms into slippery lumps when wet, drains very slowly, and shrinks greatly in drying. Such material should

not be flushed if it is desired to have no settlement.

Of the three methods of flushing described, the one in which a strong stream of water is played into the trench is undoubtedly the best, as the force of the stream faciliates the breaking up of lumps and tends to force the smaller particles into the interstices between the larger ones.

Tamping and Flushing.

After experiencing the difficulties of tamping wet loam and of flushing clay, it was thought well to combine the two methods. For this purpose a trench of the same size as those in the former experiments (6' x 2' x 4½') was refilled with 2½ feet of clay well tamped, and the remainder with loam

flushed in layers by a strong stream from a hose. The result was all that could be desired, no settlement whatever occurring during an interval of six months. By this method the material was not only handled in such a way that it was thorougly compacted, but also with the least expenditure of time and labor.

Summary

In summing up the results of the foregoing experiments it may be briefly stated that when the back-filling material is clay, or any earth of which clay forms a considerable part, the work should be done by tamping in layers, the material being comparatively dry. When

working in loam or sandy soil the back-filling should be done by flushing in layers. When both loam and sand are encountered in excavating a trench, they should be kept separate and each be put in as described above. No experiments were made with pure sand, and hence no conclusions can be drawn for that material.

It should be understood that the methods described in this article are to be applied only where trenches are opened in city streets or where it is imperative to avoid settlement. The cost of re-filling a trench so as to prevent settlement may in some cases seem excessive; but it should be remembered that this

expenditure will undoubtedly save a large amount of future trouble and expense.